Nanobioengineering/Bioelectronics Laboratory
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Project 1: *Wearable Biosensing Device for Dehydration Assessment*

The main objective of this project is to design and make a wearable sensor to measure skin impedance and communicate wirelessly with computing unit which is preferably mobile phone in which the bio-impedance values can be correlated to the hydration level of body calculate the hydration level of the body by. Dehydration is one of the leading causes of several symptoms such as a chronic headache which lower the quality of daily human activity. Also, dehydration has significant effect on the performance of athletes during their training and completions. Commercially available hydration measurement devices are not convenient and portable. Therefore, hydration level of the body cannot be measured in real time. Six major factors to be taken into consideration are as follow:

- Choosing biocompatible and electroactive material for electrode. - The design of the electrical circuit
- Design the sensor structure and fabrication method.
- Programing the microcontroller for wirelessly communication

- Design a user-friendly mobile application
- finding proper phantom model for testing and calibration

Project 2: *Optimized Sensitivity of Surface Plasmon Biosensor Using different Shaped Nanoparticles*

Localized Surface Plasmon (LSP) resonance effect is mostly found in non-metal nanoparticles. The phenomenon happens with the oscillation of valence electrons when absorbing wavelengths from the ultra violet range. Using a spectrometer, such as Surface Plasmon would be the most efficient way to measure the effect of LSP. It is also mentioned in the research that some catalytic activities could be increased by this phenomenon. Specific activities could be controlled and optimized using different metallic and non-metallic nanoparticles of different sizes in the design.

On the other hand, research has shown that integration of electrochemical control into the Surface Plasmon Resonance could increase the oxidation state of some molecules and the molecular activity could happen under a desired controlled condition, while the kinetic analysis of the interaction is monitored via the SPR machine.

Given the well-known technique of electrochemical SPR (EC-SPR), the abovementioned design of several sizes of nanoparticles could be integrated into a device compatible sensor, or even could be introduced into the system through a fluid flow. Integration of nanoparticles in the design to trigger the LSPR effect, while controlling the interaction of the molecules and recording their kinetic activity via EC-SPR, will provide promising outcomes to be further used to model the in vivo environment of a normal or diseased cell/tissue, monitoring of specific analytes, drug delivery and medical diagnostics.

Applied Neural Interfaces Laboratory
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Project 1: *Brain-Computer Interface Testbed*
Brain-computer interfaces (BCIs) translate the brain's abstract electrical activity into purposeful command signals that are used by paralyzed patients to pilot power wheelchairs or move prosthetic limbs. However, because of the dangers associated with invasive brain recordings, advances in BCI technology are slow. To overcome this barrier to progress, students will develop a BCI simulator that substitutes raw brain signals with other body signals that are safer to obtain, such as hand or body posture. Students will then supervise healthy volunteers as they control interactive video displays using these body signals, mimicking the operation of BCIs. The knowledge gained from these experiments will advance our understanding of how people interact with abstract control signals when using BCIs, and help guide the development of computer algorithms designed to assist paralyzed patients during real BCI use.

Project 2: *Electrical Stimulation of Peripheral Nerves*
Compromised bladder function is an enormous problem worldwide and occurs very often in older adults and in patients with a wide variety of neural disorders, such as diabetes, spinal injury, and multiple sclerosis. The root cause of bladder dysfunction is frequently neural weakness (neuropathy), which interferes with the healthy reflexes that regulate voiding. To address this pervasive health issue, students will electrically stimulate the bladder, urethra, and their associated sensory nerves in acute animal models in order to hijack and enhance the function of bladder-emptying reflexes. Students will employ various engineering techniques, such as numerical optimization and stochastic resonance, to identify the most effective stimulation methods and parameterizations. The successful project will lead to the development of new stimulation-based treatments for a range of bladder dysfunctions.

Optical Imaging Laboratory
PI: Dr. Anuradha Godavarty
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Project 1: *Wound Imaging using Near-Infrared Optical Scanner*

A near-infrared optical scanner has been developed for wound imaging and differentiating healing from non-healing wounds, successfully demonstrated with over 90% sensitivity and specificity in the clinic. Ongoing efforts are focused on extensive clinical studies at multiple clinical sites in hemodynamic imaging of the wounds (e.g. diabetic foot ulcers, venous leg ulcers etc.) in collaboration with dermatologists, podiatric surgeons, nursing and computer science faculty. The participating clinical sites would local clinics as well as Jackson South and University of Miami Hospital. The work involves multi-clinical site imaging studies and statistical analysis to determine the efficacy of the device in the area of wound healing.

Project 3: Breast cancer pre-screening using an ultraportable optical scanner

Breast cancer pre-screening is currently carried out by clinical or self-breast examination with no objective tool for triaging people for mammography. Herein, a near-infrared optical scanner has been developed for prescreening breast cancer. Preliminary in-vivo studies on normal breast tissues with simulated tumors demonstrated that the device can detect these tumors up to 8 cm deep. Current focus is to expand the studies to in-vivo breast cancer subjects in conjunction to x-ray mammography and determine the performance of the device in detecting any abnormalities in the breast. Work involves collaborations with radiologists, breast surgeons, computer science faculty, and extensive clinical experience.

Cardiovascular Matrix Remodeling Laboratory

PI: Dr. Joshua Hutcheson
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Project 1: *Inflammation resolution and cardiovascular remodeling*

Inflammation-driven fibrosis and calcification in cardiovascular tissues is a leading cause of death. Anti-inflammatory treatments have proven ineffective at preventing this remodeling. We will explore natural inflammation resolution therapies that promote homeostasis and tissue regeneration. This could lead to a clinical treatment for this currently untreatable condition. The research will involve development of co-culture platforms to study interactions between inflammatory cells and resident cardiovascular cells that maintain tissue structure. We will study the mechanisms by which these cells communicate and the resultant changes in cellular phenotypes. We will also use animal models of cardiovascular calcification to explore the clinical benefit of inflammation resolution.

Project 2: *Exploring biomineralization in the bone-vascular axis*

Biomineralization is an important part of bone physiology but is detrimental to the function of cardiovascular tissues. Any viable therapy for cardiovascular calcification or osteoporosis must affect one tissue without off-target effects in the other. We will use advanced imaging and material-based analyses to identify overlapping and divergent mechanisms in these processes. This work will involve cell culture models of bone and cardiovascular mineralization, optical and electron microscopy, Raman spectroscopy, and mass spectrometry.

Project 3: *Unraveling cellular contributions to aortic valve disease*

The aortic valve has poorly defined cell populations. The cellular complexity arises from different embryonic origins. We will study the interactions between the different cell populations in the aortic valve to discover new therapies for aortic valve disease and to design tissue engineered valve replacements. To do this, we will design new in vitro models to study the interactions between different valve cell populations. A large portion of this study will be completed with collaborators at the Biomolecular Sciences Institute to study the role of a specific population of cells—neural crest-derived melanocytes—in the maintenance of aortic valve tissue and the development of valve disease in mice.

Project 4: *Cytoskeletal alterations and extracellular matrix remodeling*

Extracellular matrix components that compose tissues are released from cells in a controlled manner that involves trafficking of small vesicles. The local mechanical environment of the cell influences the cell cytoskeleton and the release of extracellular matrix. We will study how cytoskeletal changes alter trafficking of intracellular vesicles and release of extracellular matrix components. This study will involve advanced optical imaging and molecular biology techniques to assay changes in intracellular trafficking. Outcomes of this study could lead to treatments for fibrotic remodeling of soft tissues and more rational designs for engineered tissue replacements.

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Adaptive Neural Systems Laboratory
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Project 1: *Prosthetic Alignment and Amputee Balance Training System*

Students will collect gait and balance data in healthy non-amputee subjects wearing modified footwear. The modified footwear simulate gait changes induced in amputees due to misalignment of prosthetic foot. The primary goal of the project is to improve the prosthetic alignment process in amputees. In existing clinical practices the alignment process is performed by a combination of verbal feedback between the amputee and prosthetist, and visual inspection of amputee's gait performance. The data collected in this project will be used to develop a method to provide quantitative biomechanical outcome measures that can be used objectively for alignment of prostheses. The data will also be used to develop a biofeedback balance/gait training paradigm in amputees to reduce the fear of loss of balance.

Project 2: *Mechanical egg design and development*

Students will design and fabricate a mechanical egg. A mechanical egg is a device that uses variable stiffness to simulate the brittleness of an egg. The goal is to have a device that can be used in an experiment with amputees. The amputees will use their prosthetic hand to pick up the mechanical egg without breaking it. The student will design the mechanical egg. Then the student will 3-D print the design and test it in order to get it ready for the experiments. Previous experience with Solid Works/CAD design is preferable but not necessary. The student will learn how to use Solid Works and how to 3-D print.

Project 3: *Sensory and motor perception*

Students will study the effect of sensory substitution on sensory perception. Sensory substitution involves providing sensory feedback by vibrotactitle stimuli on the skin. Students will use a vibrotactile array to provide information about objects of different sizes and/or compliance to non- amputee and amputee participants. The goal is to understand if functional sensory feedback can be provided to amputees in the form of vibration to the skin. The significance is that current prosthetic devices do no provide sensory feedback and thus users stand to benefit from this non-invasive technology.

Drug Delivery and Imaging Guided Therapy Laboratory
PI: Dr. Anthony McGoron
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Project 1: *Sentinel Lymph Node imaging*

Students will synthesize fluorescent labeled silica nanoparticles and inject them into the footpad of a mouse to image lymph flow. The goal is to develop a method that can accurately identify the sentinel lymph node (the primary lymph node draining a tissue bed) to spare 2nd and 3rd generation nodes. The significance is that accurate staging in breast cancer, determining if the cancer has spread, requires finding the sentinel lymph node and seeing if there are cancer cells located there (that is, to know if the cancer has spread). Surgeons need to be able to confidently locate the sentinel lymph node for dissection to reduce the potential for causing lymphedema in the patient, a condition that can be very debilitating.

Project 2: *Calibration of Fluorescent imager*

Students will create phantoms of various organs (liver, spleen, heart, lung, kidney etc) using gelatin. Fluorescent dyes at different concentrations will be mixed with the gelatin to simulate the imaging agent distribution to organs. The fluorescent dye in the organs will be imaged and compared to calibration curves to verify that the imager can be used to accurately measure the amount of dye in an organ. The significance is that conducting studies of the distribution of drug in the body (biodistribution) typically requires homogenizing the tissue and extracting the dye from the organ tissue to be measured in a spectrophotometer. It is labor intensive and prone to error. Being able to use a fluorescent imaging system has the potential to increase throughput and accuracy when studying the biodistrution of newly developed drugs.

Medical Photonics Laboratory
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Project 1: *Improving on two wavelengths retinal oximeter*

Briefly the technique works as follow: two images of the fundus are acquired with a fundus camera or equivalent tool, one in the green region of the spectrum (isosbestic wavelength) and one in the red region of the spectrum. Pixel intensity values on the vessel and near the vessel are used to calculate the local optical density (OD) at each wavelength. A calibration step is then applied, one artery and one vein within the visual field are selected their optical density is calculated as described above. Values of oxygen saturation taken from the literature (95% for arteries and 70% for veins) are imposed to the calibrating artery and vein and then used as known parameters to calculate oxygen saturation for all other wavelengths. The technique is gaining popularity because of its simplicity and consistent results on a single patient, yet the validity of the technique vis-à-vis large epidemiologic studies remains to be confirmed.

We have utilized a Monte Carlo model of light transport in the retina to determine the error associated with the two-wavelength technique and have shown that a new calibration methodology is necessary to make this technique viable for clinical use. The student will work both on instrumentation design and computational modeling to create a new calibration paradigm for retinal oximetry.

Project 2: *Oral Mucosa Vessel Density*

The main goal of this study is to develop a system to measure vessels in the oral mucosa, oral mucosal vascular density (OMVD) in combination with a Kolmogorov complexity algorithm [14] can be used to assess the probability of an individual to be either FAP or HNCPP positive.

- • A user friendly general user interface based on Matlab or other software that controls a camera and calculates the OMVD.
- • Testing of the system on optical standards
- • Testing of the system in human subject –Possible IRB
- • Can the system be used to measure vascular flow?

Project 3: *An Imaging Pulse Oximeter Based on a Multi-Aperture Camera*

Our imaging technique is based on synchronizing an imaging system to a photoplethysmographer. Photoplethysmography is the monitoring of time-varying changes in the volume of blood for a tissue. Light is directed onto an area of the skin and a photodetector is used to detect the light that is either reflected or transmitted through the skin, blood, and other tissue; the change in intensity is correlated to the change in blood volume. Within the plethysmogram signal, there is an AC signal and a DC signal. The AC component is a cardiac-synchronous signal caused by the arterial pulse and the DC component is a slow varying signal that is primarily caused by the total blood volume in the skin [6]. In a study done by Verkruvsse et al. [3] a consumer grade video camera was used to visualize the photoplethysmographic signal and determine a patient heart rate. With some additional filtering, they were able to distinguish arterial vasculature. Filtering was necessary because the DC component of the plethysmograph results in

an offset that makes it difficult to know where the peak and trough are. By removing the DC offset arterial flow could be visualized. Their system used a broadband RGB filtering given by their specific imaging apparatus; consequently, quantitative data could not be ascertained.

We propose a technique that uses a plethymographer to trigger the multi-aperture camera and take a snapshot at the peak and at the trough of the pulse waveform, the acquired images are finally used to calculate a value proportional to arterial oxygen saturation of the superficial skin vasculature

Neuronal Mass Dynamics Laboratory
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Project 1: *Microcircuits*

By using geometrical and functional descriptors from fluorescent images, we have recently developed multi-compartmental models of different neuron types and used them to simulate the activity of neuronal masses through parallel MATLAB code running in clusters and networks of personal computers. These biophysical models of the cellular/tissue architecture have been employed in the laboratory to fuse and interpret observable data from different neuroimaging modalities.

One of the focus of the team is to determine the relationship between the cellular/tissue architecture and brain functions with emphasis on: a) the role of neuronal morphology in the mechanisms for information processing, b) the optimal ways to wire the brain "from microcircuits to global graph theory" and c) the relationship between neuronal excitability (spiking – outputs, M(S)UA) and presynaptic input reflections (local field potentials, LFP). We previously worked on using multi- photon calcium imaging and whole-cell patch clamp in acute slices of the cerebral cortex of Wistar rats to formulate realistic biophysical models for the genesis of LFP/M(S)UA by large layer V pyramidal cells. In collaboration with NeuroNexus, a high-resolution 3D silicon-probe that comprises 128 microelectrodes arranged within 1 mm3 cortical volume was developed. By the use of this groundbreaking technology, the group has been able to study neuronal excitability not only at the level of neuronal masses but also that related to the activity of single neurons. A major interest of the group is the characterization of the coding/decoding strategie in the somatosensory cortices of rodents (e.g. complex representation of whiskers in the barrel field). We currently collaborate with Dr. Ranu Jung to study brain plasticity in amputees from brain neuroimaging techniques (e.g. EEG, TMS and fNIRS), with particular interest on: a) creating new strategies for the transduction of sensory information and motor commands into neuronal signaling and b) studying brain plasticity, adaptive mechanisms for multimodal sensory integration and motor planning in rodents/humans with amputations.

Project 2: *Neurovascular Coupling*

In the past, I have developed models for fusing EEG and fMRI multimodal data based on the major principles for the genesis/diffusion of nitric oxide, a well-studied phasic pathway connecting neurons and vessels in the cerebral cortex. Such models were used to interpret multimodal experimental data from humans undergoing visual, somatosensory and motor tasks. These models have been additionally useful to understand the large-scale functional connectivity profiles in the human brain from combining hemodynamic/metabolic-based imaging modalities and electrophysiological data. Recently, I have developed a novel mini-cap for whole head EEG recording in rodents, which is currently under consideration for US patent. Based on this patented technique, members of the team record EEG signal concurrently with local blood flow activity (Laser Doppler flowmeter, Perimed Inc, US) and O2/NO tissue metabolism (Amperometric microsensor, Unisense, DA) under a variety of pharmacological manipulations in vivo. To perform data fusion and proper stimulation protocols in Wistar rats, we have developed a brain probabilistic atlas for this particular species and introduced novel methods for image co-registration.

Of particular interest is the comprehension of the role played by the protoplasmic astrocytes in: a) the modulation of neuronal activity, b) signaling-based regulation of local brain metabolism and c) vessel controllability, both in normal and pathological brains. For that aim, I have developed a novel technique based on the combination of multi-photon calcium imaging and multi-side intracranial recordings in vivo from rodents. To study hemodynamic and metabolic abnormalities in the epileptic tissues, this technique is being now extended in collaboration with Dr. Wei-Chiang Lin to other optical imaging modalities (e.g. diffuse reflectance spectroscopy). With the help of optogenetic methods and fluorescent-loading protocols, the latter approach allows our team to quantify those astrocytic-derived factors with actions into both the neuronal networks and the cerebral microcirculation. In the past, I had postulated that dysfunctions in the astrocytic networks might be an important component in the physiopathology of Alzheimer disease. The introduction of biophysical models for the genesis and propagation of intercellular signaling has been crucial to evaluate the imprints left by brain disorders in functional neuroimaging. In collaboration with Dr. Nikolaos Tsoukias, biophysical modeling is combined in our laboratory with transgenic and multi-cellular co-culture techniques to study the role played by intercellular Ca2+ and NO signaling in several brain pathologies (e.g. dementia, hypertension).

Project 3: *Neuro-Inflammatory Processes*

In the last five years, I have focused on understanding astrocytic calcium signaling in both normal and pathological brains. Being a pioneer in combining intracranial recordings and multi-photon laser scanning microscopy in vivo to access the activity of networks of neurons and astrocytes, I have also used similar techniques to study dysregulations in the astrocytic calcium activity caused by deposition of β-amyloid plaques. It is worth to hypothesize that early cyto-architectonic malformations (e.g. FCD lesions, strokes, Ab plaques) might create progressively astrogliosis evoked by undergoing inflammatory processes, and consequently, cause local dysregulations in the astrocytic calcium signaling. The main objective of this research line is to determine the major causes of both alterations in astrocytic calcium signaling and the associated inflammatory signaling associated with brain lessions, as well as to develop an optogenetic method to prevent these alterations, and hence, the possible development of epileptic seizures. A non-invasive control with light stimulation of such dysregulations in the astrocytic calcium activity is expected to interrupt the mechanisms for the novo- synthesis of pro-inflammatory signals. The optical system needed for this research line is being developed in collaboration with Dr. Wei-Chiang Lin.

Tissue Engineered Mechanics, Imaging and Materials Laboratory
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Project 1: *Histology, Immunostaining and Histomorphometric analysis of engineered tissue valves*

In the treatment of heart valve disease, we are currently engineering heart valves using stem cell protocols or in other cases using decellularized scaffolds. An important outcome requires assessment of cell and tissue morphology within the constructs. This includes, biochemical distribution, phenotype identification and native tissue integration assessment. Thus histological/immunohistochemistry assessment will be a major focus of this project.

Project 2: *Fluid-Induced shear stress culture of valve endothelial cells*

An important regulator of valve endothelial cells (VECs) is the localized shear stress environment. We wish to assess the response of VECs, including the underlying gene and molecular mechanisms that may lead to both normal and pathological valve tissue remodeling. Cell culture under normal, surgically-corrected and pathological shear stress environments will be a central focus of this project.

Plasticity, Monamines and Recovery of Function Laboratory
PI: Dr. Jacob McPherson
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Project 1: *Recurrent neural-computer interfaces for neuropathic pain*

Project description: up to 80% of individuals with spinal cord injury (SCI) experience debilitating, medically refractory neuropathic pain. In part, this pain may be related to maladaptive over-activity in specific spinal pain-processing neurons. Recurrent neural-computer interfaces (rNCI) are an emerging technology that uses biophysical signals recorded from one area of the body/nervous system to trigger contingent stimulation (e.g., electrical, chemical) in another region of the central or peripheral nervous system. Such artificial neural connections can be used to facilitate and guide beneficial neural plasticity and/or to produce specific movements or sensations. In this project, we aim to use rNCI to selectively weaken over-active neural circuits by driving activity-dependent neural plasticity. The project draws primarily from the broad fields of basic neurophysiology, animal models of SCI, biophysical signal processing, data acquisition/instrumentation, and electrical engineering.

Project 2: *Sensorimotor integration as a window into neurological impairments*

Project description: injuries to the central nervous system such as stroke and spinal cord injury frequently result both in motor deficits and changes in sensation (ranging from muted pain perception to the presence of spontaneous neuropathic pain). Although a growing body of evidence suggests that an increased influence of specific neuromodulatory centers in the brainstem reticular formation may underlie both the sensory and the motor changes, the majority of investigations only consider one or the other. Thus, in this project we will investigate the pain-motor dynamic in humans by using a combination of mechatronic devices, psychophysical analyses, and biophysical signal processing. The goal of the project will be to quantify how changes in volitional motor output impact sensory acuity, and how painful and non-painful sensory stimuli impact volitional and reflexive motor output.

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PI: Dr. Shuliang Jiao
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Project 1: *Application of Optical Coherence Tomography (OCT) in ocular biometry:*

The project will apply OCT to image the anterior segment of animal eyes to measure the growth of the eye with age. The project will provide normative date for the design of contact lenses for animal imaging. The project will also identify the lesions of the eye surface and examine the effects of these lesions on the imaging quality of the retina. Students will need to be familiar with Matlab to be eligible for the projects.

Project 3: *Imaging the fluorophores of the eye*

This project will apply quantitative imaging method to characterize the fluorescent properties of the major fluorophors in the retina such as lipofuscin. Both in vivo an ex vivo imaging will be performed on animals and human donor eyes. The project will help establish the relationship between light intensity and wavelength with the fluorophor concentration, which will eventually contribute to the in vivo quantification of lipofuscin in the retina.

Project 3: *Innovative animal fixation methods and devices for in vivo retinal imaging*

This project will focus on the development and validation of new animal fixation methods to provide effective stabilization of the eye. The animal fixation methods will help minimize eye motion artifacts in in vivo retinal imaging. The project will be developed on the basis of our current animal fixation methods.

Biomedical Engineering Creative Lab: W[CL]^2

PI: Dr. Wei-Chiang Lin
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Project 1: *Wireless Biopotentials*

Electrocardiography, Electromyography, and Electrocorticography are all examples of biomedical techniques to characterize physiological events by measuring electrical potential on the body. Integrated with RFID technology, we can design low-power wireless medical devices that are more accessible than their wired counterparts and have longer usage time than bluetooth and wifi powered devices. Students interested will need prior knowledge of Circuits 1, Circuits 2 experience (op-amps, transistors, filters) encouraged. Programming experience encouraged but the primary language will be C. Basic understanding of the Heart, Muscles, and Brain are necessary. All circuit designs will start from scratch "on the bench" (microprocessors, discrete components) with the intent to transition into integrated components.

Project 2: *Digital Anatomy of Cortex*

In the Digital Cortical Anatomy Lab (D-CAL) here at FIU, we produce high-resolution, detailed 3D models of the intricate network architecture of neurons, astrocytes and vasculatures in the cerebral cortex of the brain. While these 3D models are essential for visualizing how different regions of the brain (i.e. visual cortex, motor cortex, somatosensory cortex, etc.) are physically composed of these primarily cell types, the project is now at the stage where software packages must be written to extract specific quantitative parameters in order to compare different regions of the brain or normal from diseased tissue.

This project will require you to utilize Matlab, a programming interface, to import the 3D models generated and develop algorithms to quantify particular aspects of connectivity, such as a tripartite synapse.

Project 3: *Touch-Screen based Scanner*

The objective of this project is to develop an App that utilizes the touch screen of a smartphone or a tablet to scan contents printed with conductive materials. This is a part of the project aiming to create a user-friendly record keeping and reminder system. It is suitable for someone who is highly interested in advancing his/her programming skill and developing apps.